West Coast Regional Carbon Sequestration Partnership
westcarb.org

Geologic Sequestration of CO_2

Trapping Carbon Dioxide (CO_2) in the Earth

Course #101

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Course syllabus

- What is CO_2 and how are we making it?
- Why is CO_2 a problem?
- Where would CO_2 go in the earth and how would it be trapped?
- Would there be a big bubble of CO_2?
- For a small-scale test project, what are we testing?
- What are we <u>not</u> testing and why?
- What's involved in field operations?
- Who else is doing projects like this?

What and where is carbon dioxide?

- The bubbles in carbonated beverages are CO_2
- The dry ice in old ice cream trucks was frozen CO_2
- CO_2 is in the air we breathe


Sources of CO_2

- Fire
- Cars, trucks, airplanes
- Electricity generation at coal and gas fired power plants
- Oil refineries
- Cement plants
- Forest fires

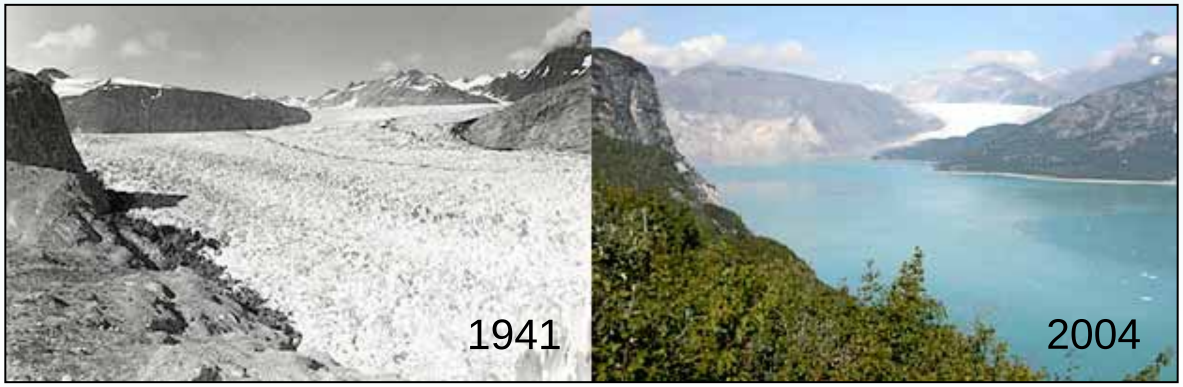




Why is carbon dioxide a problem?

- CO_2 in the atmosphere acts like the glass in a greenhouse – it traps in heat
- Plants absorb CO_2 and produce oxygen, but we produce more CO_2 than can be absorbed
- The amount of CO_2 in the atmosphere is increasing
- The average temperature of the atmosphere is increasing
- The polar ice caps and glaciers are melting
- Sea level is rising
- Storm frequency and severity is increasing
- Weather patterns are changing
- Many crop lands are threatened

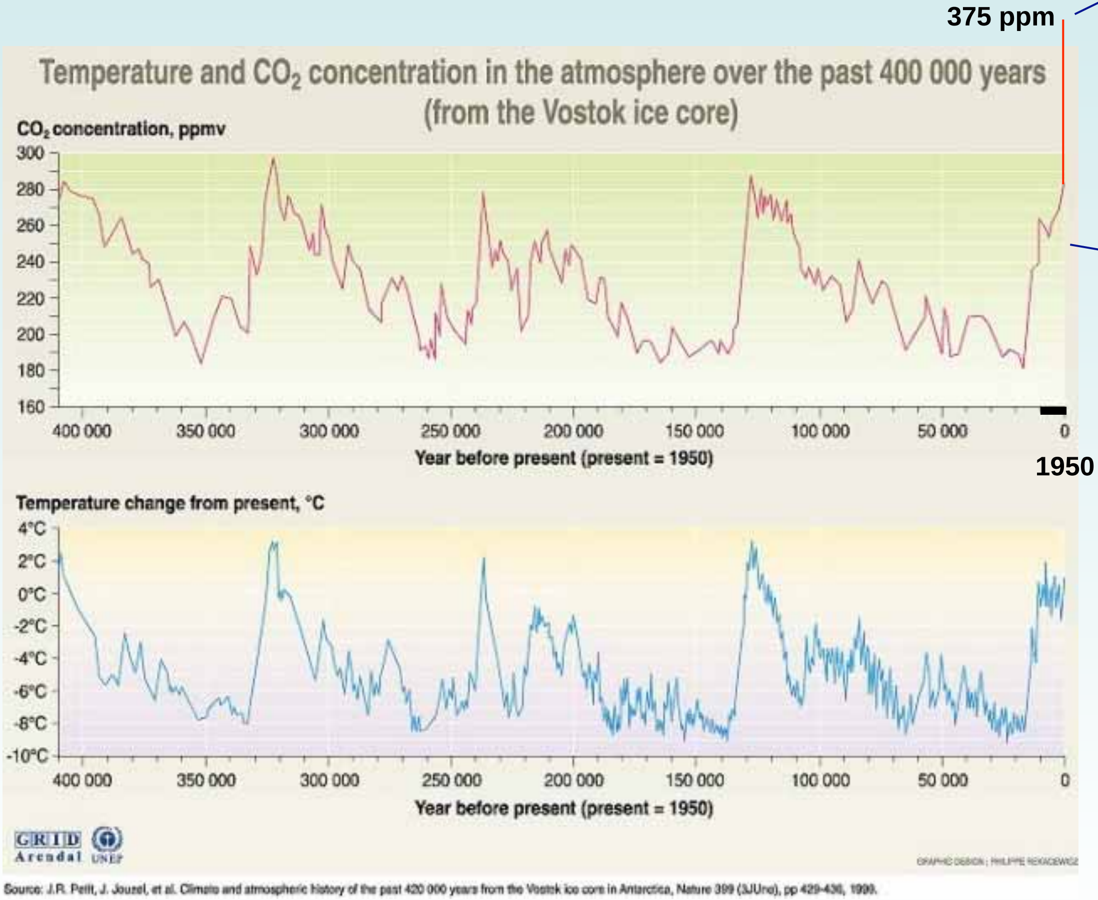
Muir Glacier
Alaska

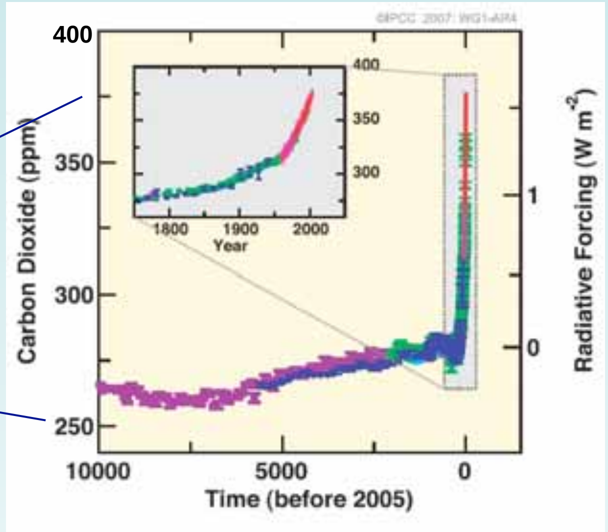


53 years later

Image Credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia

CO_2 concentration and Earth's temperature

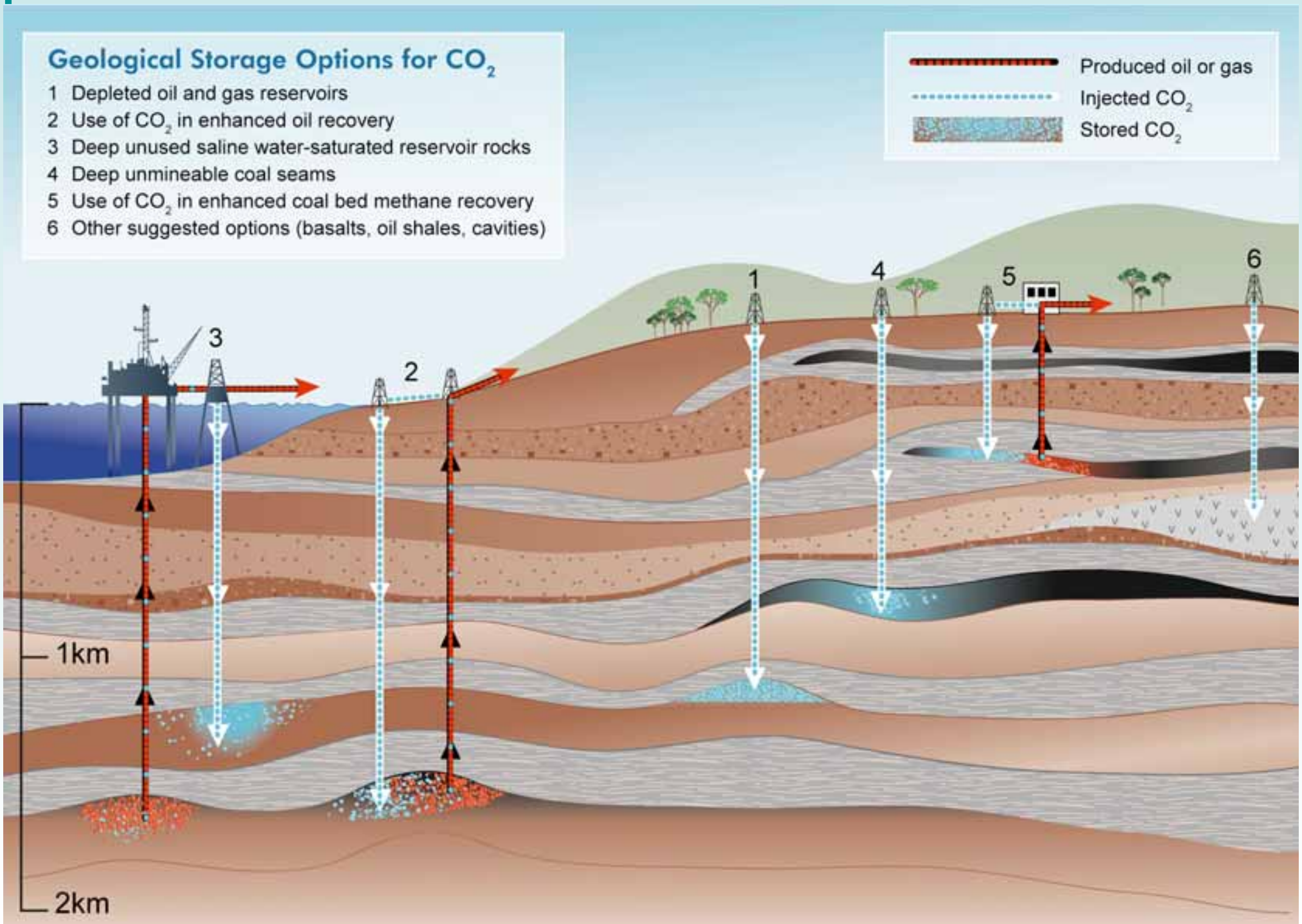




Source: IPCC Working Group 1 as presented at http://www.oneclimate.net/2008/01/15/climate-change-the-truth-greenhouse-gases/

Source: United Nations Environment Programme. GRID-Arendal. Vital Climate Graphics. ISBN: 8277010095.

Geologic CO_2 storage



Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

Important rock types for CO_2 storage

Cap Rock

Commonly, Shale

- In sedimentary basins it is laterally extensive, thick, and has very fine grains, which makes it relatively impermeable.
- Has held oil and gas in reservoirs for millions of years.

State of Utah, Office of Education, www.usoe.k12.ut.us

"Bedford Shale", *Ohio History Central*, July 13, 2007, http://www.ohiohistorycentral.org/entry.php?rec=2857

Reservoir (storage) Rock

Commonly, Sandstone

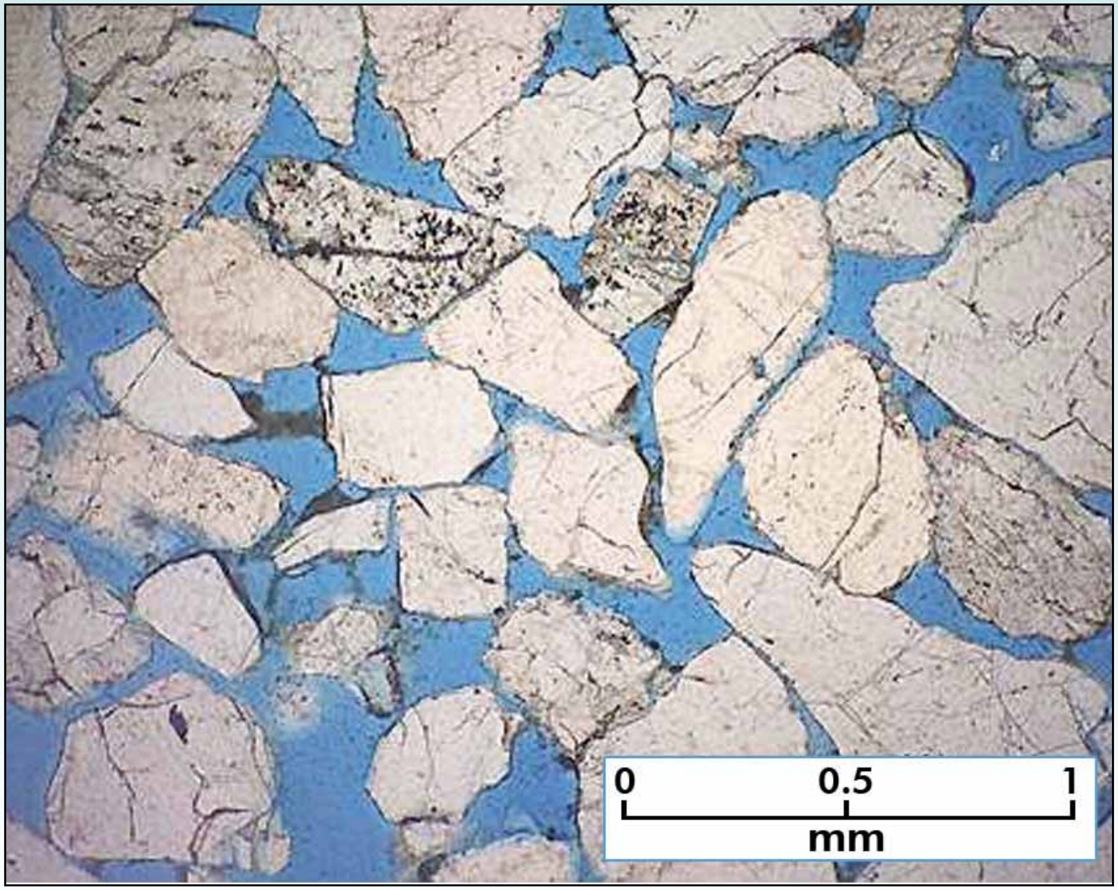
- In sedimentary basins it is laterally extensive, thick, and has high porosity and permeability.
- Most common oil and gas reservoir rocks.

Bureau of Economic Geology, University of Texas

http://library.thinkquest.org/05aug/00461/images/sandstone.jpg

Reservoir rock porosity and permeability

Microscopic view of sandstone



Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

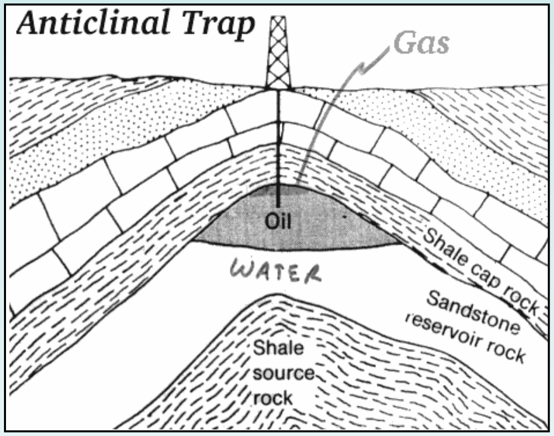
The pores in deep rock formations are filled with saline water (brine).

In oil and gas reservoirs, the pore space is filled with hydrocarbons.

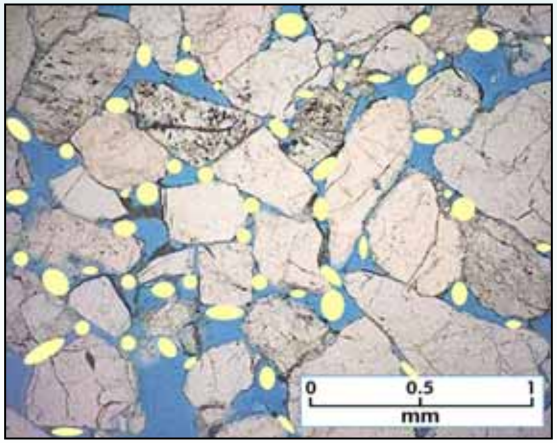
CO_2 both dissolves in and displaces some of the brine.

How CO_2 is trapped deep in the earth

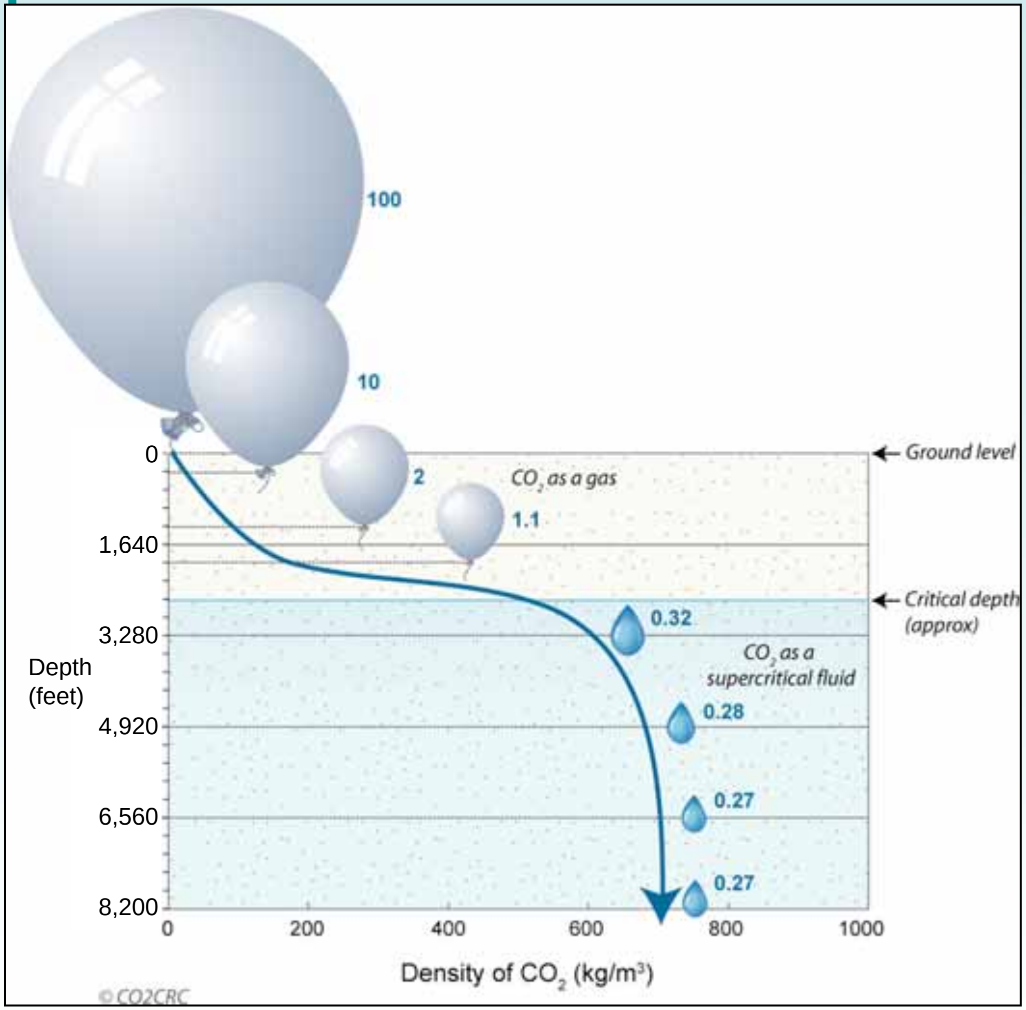
1. Dissolves in saline water in the reservoir rock (like CO_2 dissolved in a soda)
2. Impermeable overlying cap rock and dome-shaped structures (the way oil and gas are trapped)
3. If the plume moves from buoyancy, water fills in behind it, trapping bits of CO_2 in tiny capillaries between the pores of the reservoir rock
4. Chemical combination with minerals dissolved in the formation brine to form new rock



Earth Science Australia, http://earthsci.org/education/teacher/basicgeol/fossil_fuels/anticlinal-trap.gif



Will there be a big bubble of CO_2 in the ground? No - CO_2 is very compressible



Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)

CO_2 compresses by a factor up to 370 from its volume at the surface.

The hydrostatic (water) pressure in the rocks increases by about 1/2 psi per foot of depth in the earth.

So the CO_2 stays compressed by the pressure that naturally exists deep in the earth.

The compressed CO_2 is liquid-like, with about 2/3 the density of water.

For a small-scale CO_2 injection test project, what are we testing?

- Do the deep potential reservoir rocks have high porosity to contain large quantities of CO_2?
- Do these reservoir rocks have high permeability so CO_2 can be injected?
- Are there impermeable rock formations or structures above the CO_2 reservoir that will contain the CO_2 indefinitely?
- How will the CO_2 interact with the rock and the saline water in the pores of the rock? - so we can predict when and where the CO_2 plume will stabilize
- What techniques will work best to monitor the movement of the plume until it stabilizes?

For a small-scale CO_2 injection test project, what are we <u>NOT</u> testing?

- Can we safely drill deep wells and pump large quantities of CO_2 down them?

  In the United States today, the oil industry is pumping more than 85,000 tons of CO_2 into the ground every day (31 million tons/year)

- Can we safely transport CO_2 from industrial sources to the wells?

  For small quantities, many CO_2 tanker trucks are traveling on our highways every day to supply CO_2 to beverage manufacturers.

  For large quantities, the oil industry has a 2,200-mile CO_2 pipeline network that has operated safely for decades.

Why are the oil companies injecting large quantities of CO_2 into the ground?

Enhanced Oil Recovery (EOR)

- CO_2 EOR recovers 206,000 BOPD, 12% of lower US oil production
- Started in 1972, it is responsible for more than 1 billion barrels of oil from the Permian Basin
- There are more than 72 US oil fields using the 85,000 tons per day

- The source of CO_2 for EOR is deep geologic formations where nature has stored it for millions of years!

Field operations for test
Step 1 – Drill wells

An oil & gas drill rig capable of drilling to several thousand feet is used

This rig is drilling a natural gas well in northwestern California.

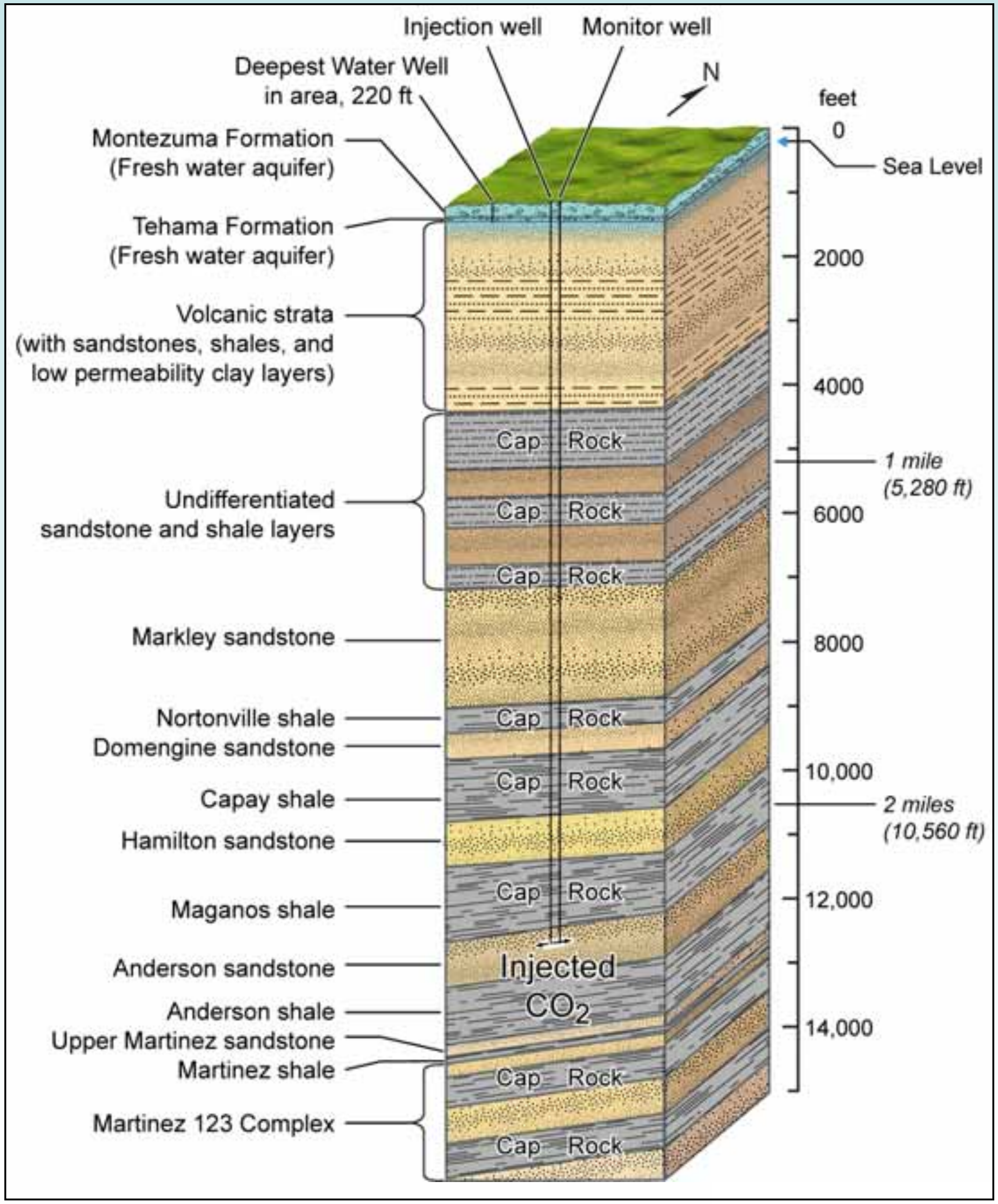
Source: Shell

Drill site for Midwest Regional Carbon Sequestration Partnership 9,000-foot well in Edwardsport, Indiana.

Source: Midwest Regional Carbon Sequestration Partnership, David Ball, Battelle

Field operations
Step 1 – Drill wells

- Two wells will be drilled more than 2 miles deep and 150 feet apart
- CO_2 will be injected into a permeable sandstone layer beneath multiple impermeable shale layers
- The CO_2 plume is expected to be about 800 feet wide



Field operations for test
Step 2 – Inject CO_2

20-ton tanker trucks will transport CO_2 to the site for injection

The excitement of CO_2 injection

Source: Gulf Coast Carbon Center, part of The University of Texas at Austin's Bureau of Economic Geology

Field operations for testing
Stage 3 – Testing and Monitoring

A crane will lower tubing and test equipment into the well

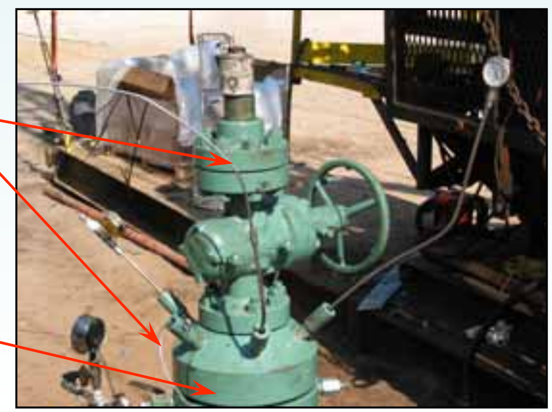
Source: Midwest Regional Carbon Sequestration Partnership

A module with office space, computer, and valves (U-Tube System) will obtain brine samples from the reservoir formation.

U-Tube System at Frio, Texas, CO_2 site

¼-inch tubes from bottom of well to surface module

Wellhead



Stage 4 – End of small-scale test project
Field site after small-scale test project

Wellhead on-site if operator retains the well for future testing or other options

If operator decides to plug & abandon the well, which would require restoring the site

Stage 5 – Optional - Large-scale injection

Whether this would happen depends on many factors

- Appropriate geologic information from the small-scale test
- Federal laws regulating CO_2 emissions
- Cost of CO_2 emissions
- Nearby sources of CO_2
- Pipeline from sources to injection site
- Acceptance by regulators and the public

CO_2 Storage Projects Around the World

Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)